THE INTELLIGENT CONTROL OF AN INDUCTION MOTOR

Eleonora DARIE[1*], Emanuel DARIE[2], Valentin TCANCENCO[3]

In this work on describes the control of an induction machine using the principle of direct torque and flux control. This method is designed by means of fuzzy logic with three inputs and three outputs. For improvement of this method a fuzzy duty ratio controller is added. In this control the selected inverter switching state is applied for a portion of the switching period. The control is verified by simulation.

Keywords: induction motor, direct torque, flux control, fuzzy control, speed control.

1. Introduction

The Induction motors (IM), particularly the squirrel-cage induction motor, enjoy several inherent advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives. However, for high dynamic performance industrial applications, their control remains a challenging problem because they exhibit significant non-linearities and many of the parameters, mainly the rotor resistance, vary with the operating conditions. The Field orientation control or the vector control of an induction machine achieves decoupled torque and flux dynamics leading to independent control of the torque and flux as for a separately excited DC motor. The field orientation control methods are attractive but suffer from one major disadvantage: they are sensitive to motor parameter variations such as the rotor time constant and an incorrect flux measurement or estimation at low speeds Thus, performance deteriorates and a conventional controller such as a PID is unable to maintain satisfactory performance under these conditions.

Recently, there has been observed an increasing interest in combining artificial intelligent control tools with classical control techniques. The principal motivations for such a hybrid implementation is that with fuzzy logic and neural networks issues such as uncertainty or unknown variations in plant parameters and structure can be dealt with more effectively, hence improving the robustness of the control system. Conventional controls have on their side well-established

[1] PhD, Electrotechnical Department, Technical University of Civil Engineering, Bucharest, Romania (*Corresponding author)
[2] PhD., Engineering Department, Police Academy of Bucharest, Romania
[3] Prof., Engineering Department, Police Academy of Bucharest, Romania

theoretical backgrounds on stability and allow different design objectives such as steady state and transient characteristics of the closed loop system to be specified.

In this work the method of direct torque and flux control (DTFC) on introduced and applied to an indirect field-oriented induction motor.

This method is characterized, as deduced from the name, by directly controlled torque and flux and indirectly controlled stator current and voltage [1]. It is an alternative dynamic control for the vector control. The big interest in DTFC is caused by some advantages in comparison with the conventional vector-controlled drives, like: the control is without using current loops; the drive does not require coordinate transformation between the stationary frame and synchronous frame; a pulse-width modulation (PWM) modulator is not required.

The method DTFC has also some disadvantages: possible problems during starting and low speed operation; high requirements upon flux and torque estimation; variable switching frequency [2].

These disadvantages can to remove by using and implementing modern resources of artificial intelligence like neural networks, fuzzy logic [3].

2. Fuzzy logic DTFC

To obtain improved performance of the DTFC drive during changes in the reference torque, it is possible to use a fuzzy-logic-based switching vector selection process [1].

The different output voltage states (active and zero states) are selected by using three inputs: the flux e_ψ, the torque e_m errors and also the position of the stator flux linkage space vector u_s (Figure 1).

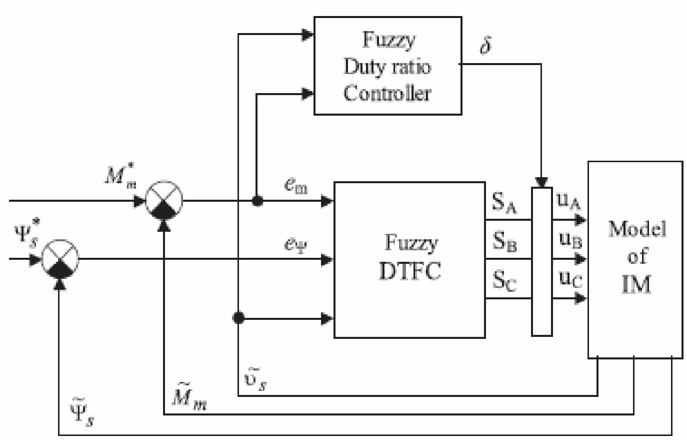

Fig. 1. Fuzzy DTFC and duty ratio controller.

The stator flux linkage space vector can be located in any of twelve sectors, each spanning over a 600 wide region. For every sector there are 15 rules. The stator flux error ($e_\psi = \Psi_m^* - \tilde{\Psi}_s$) have three fuzzy sets: stator error can be positive P, zero ZE, and negative N. For the torque error, there are five fuzzy sets: the torque error ($e_m = M_m^* - \tilde{M}_s$) can be positive large PL, positive small PS, zero ZE, negative small NS and negative large NL (Figure 2). Since there are 12 sectors, for each sector 15 rules, the total number of rules is 180.

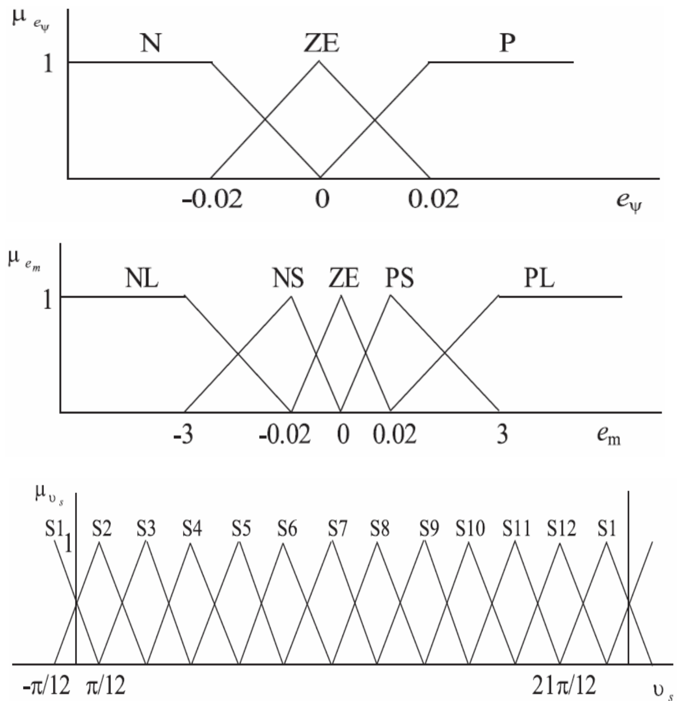

Fig. 2. Membership functions for fuzzy DTFC.

By using the minimum operation for the fuzzy operation, the firing strength of the rule (where *i* = 1, 2, ... 180), α_i can be obtained by considering

$$\alpha_i = \min\left\lfloor \mu_{Ai}(e_\psi), \mu_{Bi}(e_m), \mu_{Ci}(u_s) \right\rfloor, \tag{1}$$

Where $\mu_{Ai}(e_\psi)$, $\mu_{Bi}(e_m)$, $\mu_{Ci}(u_s)$ are the membership functions of the fuzzy sets *Ai*, *Bi* and *Ci* of the flux error, torque error and flux position and *n* is the switching state. The output from is obtained using the relation:

$$\mu_{N_i^{'}} = \min\lfloor \alpha_i, \mu_{N_I}(n) \rfloor, \tag{2}$$

where $\mu_{N_I}(n)$ is the membership function of fuzzy set N_i of variable n.

The outputs from the fuzzy system are crisp numbers (switching state n), and for defuzzyfication the maximum criterion is used the relation:

$$\mu_N(n) = \max\left\lfloor \alpha_{N_i^8}(n) \right\rfloor, i = 1, 2, \ldots, 180. \tag{3}$$

2.1. Fuzzy duty ratio controller

The voltage vectors selected from the fuzzy DTFC are not optimal in some region of stator flux vector positions. These disadvantages are improved by the fuzzy controller called a duty ratio controller [1]. In this control the selected inverter switching state is applied for a portion of the sample period, defined as a duty ratio δ [3] and the zero switching state is applied for the rest of the period. The duty ratio is chosen to give an average voltage vector, which causes torque change with ripple reduction. The Fuzzy controller includes two inputs (the torque error e_m and the position of the stator flux linkage u_s according on sector) and one output (duty ratio δ).

2.1. Implementation duty ratio controller

The duty ratio controller prepares an optimal voltage vector for optimization outputs, which generate fuzzy DTFC. The fuzzy controller generates a number between 0 and 1. The Figure 3 presents this realization. The frequency of a triangular signal generator has the same value as the signal frequency from fuzzy DTFC (switching state frequency) and the value of amplitude is 1.

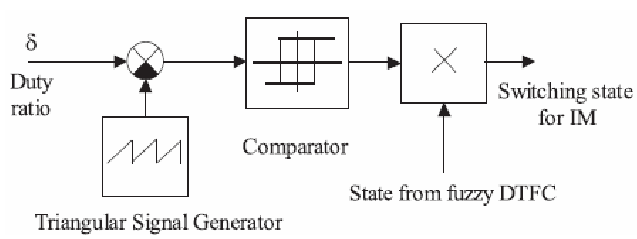

Fig. 3. Membership functions for fuzzy DTFC.

The comparator compares two signals and generates the duty ratio, which is a product with the fuzzy DTFC state. The triangular signal generator was used for pulse width modulation of outputs signal.

3. Simulations

The simulations in Simulink/Matlab verify the control. With the speed controller on the torque generator (Figure 1) we get speed fuzzy DTFC control of the induction machine. The verification of the control not needs the speed, torque and flux estimators (for sensorless control). These state values are the feedback from the model of the induction machine.

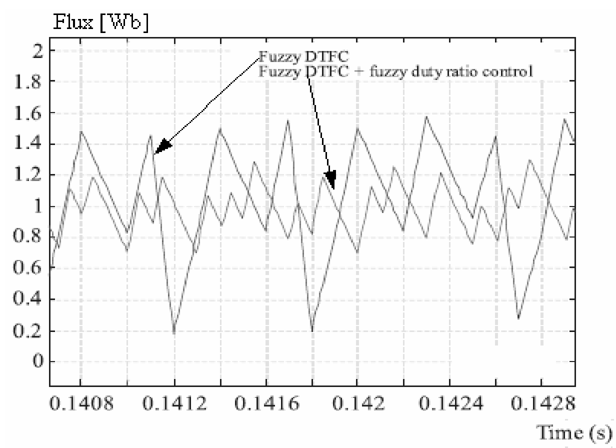

Fig. 4. Comparison torques curves (zero speed).

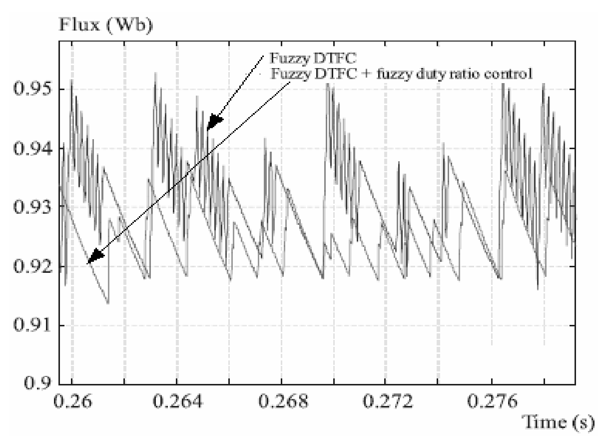

Fig. 5. Comparison stator flux curves (zero speed).

The Figure 4 shows the curves of the switching state, what is an interference of the duty ratio control.

Figures 4 and 5 presents that this method brings a decrease of the torque and the stator flux ripples.

4. Conclusions

On conclude that the fuzzy duty ratio controller brings improvements in fuzzy DTFC and in DTFC in generally.

The sample time of simulation is 0,1 ms, the voltage vector states are switched on with of frequency of 10 kHz.

The induction motor is one of such difficult systems and hence it can be considered as a challenging engineering problem for evaluating the performances of the designed controllers.

The results demonstrate the effectiveness of these control structures. The performance is maintained under rotor resistance variations, which is known to cause performance deterioration in vector-controlled induction motors.

REFERENCES

[1]. *M .A. Brodis, G. J. Oyama* "Dynamic neural controllers for induction motor", IEEE Trans. Neur. Netw., **vol. 10**, no. 2, 2001, pp. 340-355.

[2]. *S. G. Cao, N. V. Rees* "Analysis and design of fuzzy control systems using dynamic fuzzy state space models", IEEE Trans. Fuzzy Syst., **vol. 7**, no. 2, 2003, pp. 192-199.

[3]. *C. C. Chan, H.Wangs* "An effective method for rotor time constant identification for high performance induction motor vector control", IEEE Trans. Indust. Electr., **vol. 37**, no. 6, 2001, pp. 447-482.